EA486F
Flight Test IV

Flying Qualities

I. *Purpose*

A. To determine compliance with controllability, maneuverability and stability requirements.

B. To determine rudder power and aileron power; the period and the time to half of the phugoid mode; the time to double of the spiral mode; the period of the dutch roll mode; and to demonstrate the short period mode.

II. *References*

1. Etkin, Dynamics of Flight — Stability and Control, sections 2.9, 3.9, 3.10, 6.5, 7.1, 7.3.
2. Federal Aviation Regulations (FAR), Part 23, sections 23.143 through 23.181.

III. *Discussion*

A. Compliance

1. Section 23.143 of the FARS requires that an aircraft be safely controllable and maneuverable during takeoff, climb, level flight, dive and landing (power on and off) with the wing flaps extended and retracted. A smooth transition from one flight condition to another (including turns and slips) without danger of exceeding the limit load factor under any probable operating condition, must be possible.
2. Section 23.171 of the FARS requires that an aircraft be longitudinally, directionally and laterally stable. In addition, the aircraft must show suitable stability and control 'feel' (static stability) in any condition normally encountered in service.
3. The individual tests discussed in Section IV are designed to demonstrate compliance with these requirements.

B. Theory

1. Rudder power is the ability of the rudder to generatea yawing moment. It can be measured by the rudder force or rudder deflection, δ_r required to maintain a constant steady heading sideslip, or to maintain zero sideslip under the most extreme conditions of asymmetric thrust and turning flight. It is measured in terms of the ratio of sideslip angle to rudder deflection, i.e.

$$\frac{\delta_r}{\beta} = \frac{C_{n_\beta}}{C_{n_{\delta r}}}$$

where

$$\begin{aligned} \beta &= \text{the sideslip angle} \\ \delta_r &= \text{rudder deflection} \\ C_{n_{\delta r}} &= \text{rudder power derivative} \\ C_{n_\beta} &= \text{weathercock stability derivative} \end{aligned}$$

2. Aileron power is the ability of the aileron to generate a rolling moment. It can be measured by the force or aileron deflection, δ_a required to maintain a constant angle of bank in a steady heading sideslip, or by the rolling rate response to a step input of the aileron. In the first case this ability is

dependent on the dihedral effect, and in the second on the damping in roll. Only the ability to induce rolling rate is determined in this exercise.

If an aircraft in straight and level flight is banked, a gravity component, $W \sin\phi$, acts along the y-axis and induces sideslip. *Dihedral effect* is the tendency of the aircraft to roll out of the bank as a result of this sideslip. It is expressed in terms of the rolling moment due to sideslip, C_{ℓ_β}.

Because deflection of the ailerons produces a rolling moment, aileron power is expressed by the derivative $C_{\ell_{\delta_a}}$, i.e.

$$\frac{\delta_a}{\beta} = \frac{C_{\ell_\beta}}{C_{\ell_{\delta_a}}}$$

3. The period of any oscillation and time to half or double the amplitude of the oscillation are important numerical parameters. For example, military flying quality specifications require that, if the phugoid mode is unstable, the time to double the amplitude must be greater than 55 seconds. Furthermore, if the spiral mode is unstable, the time to double the amplitude from an initial bank of 20° must be greater than 20 seconds.

IV. *Procedure*

1. Dynamic Stability

   a. Phugoid Mode. Trim aircraft and set power for steady level hands-off flight at about 100–120 kts. Without changing power or retrimming, reduce speed by about 20-30 kts and release yoke. Hold heading. (Note: Be careful not to let aircraft exceed limits. If necessary, stop the motion and restart at a speed closer to the trim speed.)

      Record level flight trim IAS. Note position of nose on horizon. After pilot disturbs the aircraft and releases the yoke, wait for nose to pass below horizon; then observe airspeed indicator closely. Record maximum airspeed, and start first stop watch. For each oscillation, record the times and IAS whenever the speed reaches a maximum and a minimum. Using the second stop watch record the times whenever the VSI passes through zero.

   b. Dutch Roll. Set power, and trim aircraft for steady, level, hands-off flight at about 100–120 kts. Apply an impulsive rudder deflection (deflect rudder sharply and release). Observe the movement of the wing tip relative to the horizon.

      Note elliptic oscillation of the wing tip. Start stopwatch when oscillation commences and count oscillations. When oscillations are no longer discernible, stop stopwatch. Record total time and total number of oscillations. Describe and record the ratio of roll to yaw motion of the wingtip.

   c. Spiral Mode. Trim aircraft and set power for steady level hands-off flight at any convenient airspeed. Note position of all controls. Commence a turn, and when aircraft is banked 20° return all controls to original position and hold. Observe bank angle as a function of time.

      Start stop watches on the pilot's 'Mark'. Record time for each 10° change in bank angle.

2. Rate of Roll
   a. With gear and flaps retracted, set power to trim for level flight at 1.2 V_{S1}. Establish a steady 30° banked turn, then, using maximum aileron deflection, roll the aircraft through 60 degrees so as to reverse the direction of turn.
   b. Repeat (a) with aircraft trimmed, power set for level flight at 1.3 V_{S1} and gear and flaps extended (dirty). V_{S1} is the stalling speed flaps and gear retracted (clean, i.e., bottom of the green arc on the ASI.)
   c. Repeat (a) with idle power and aircraft trimmed for gliding flight at 1.3 V_{S1}.

   Determine the time required from initiation of roll to roll through 60 degrees of bank.

3. Trim
   a. With flaps and gear retracted, trim for straight and level flight at $0.9V_H$ or the speed at maximum continuous power (or 25"Hg/2500 RPM), whichever is lower. Release controls. Note: V_H is the speed at maximum power.

      Determine the time from the moment the pilot releases the controls until appreciable deviation from trim (10° angle of bank, 5 kts airspeed) is noted. If no appreciable deviation is noted after two minutes, discontinue the test. Ask the pilot to describe the trimmability of the aircraft in relation to the mission.
   b. With flaps and gear retracted, trim for climb with maximum continuous power (or 25"Hg/2500 RPM) and a speed between V_x and 1.4 V_{S1}. Release pitch control (yoke).

      Determine the time from the moment the pilot releases the controls until appreciable deviation from trim (10° angle of bank, 5 kts airspeed) is noted. If no appreciable deviation is noted after two minutes, discontinue the test. Ask the pilot to describe the trimmability of the aircraft in relation to the mission.
   c. With gear extended and flaps retracted, trim and set power for a 3° glide (480 feet per minute descent) at 1.4 V_{S1}. Release pitch control (yoke).

      Determine the time from the moment the pilot releases the controls until appreciable deviation from trim (10° angle of bank, 5 kts airspeed) is noted. If no appreciable deviation is noted after two minutes, discontinue the test. Ask the pilot to describe the trimmability of the aircraft in relation to the mission.

4. Static Directional and Lateral Stability
   a. Rudder and Aileron Power. Select straight road or other terrain feature aligned with surface wind. When flying straight in line with this feature, set directional gyro to zero. Establish a steady sideslip, building up to full rudder deflection and bank as necessary.

      When the aircraft is aligned with the selected terrain feature, record directional gyro reading. After pilot establishes steady sideslip, again record directional gyro reading and yoke deflection.

b. Repeat (a) at V_A. Note: V_A is the design manuevering speed.

   Note rudder pedal force reversal, if it occurs.

c. With gear and flaps up, set power and trim for level flight at 1.2 V_{S1}. Holding wings level, establish a skid building up to full rudder deflection. Report rudder pedal force reversal, if it occurs. Release rudder.

   Note rudder pedal force reversal, if it occurs.

   Note tendency, if any, to recover from skid when rudder is released. Note tendency, if any, for low wing to rise when yoke is released.

d. Repeat (a) at maximum continuous power (or 25"Hg/2500 RPM).

   Note rudder pedal force reversal, if it occurs. Note tendency, if any, to recover from skid when rudder is freed. Note tendency, if any, for low wing to rise when yoke is released.

f. Repeat (d) at V_{FE}. Note: V_{FE} is maximum flap extension speed.

   Note rudder pedal force reversal, if it occurs. Note tendency, if any, to recover from skid when rudder is freed.

V. *Flight test report requirements*

1. For each series of data points, determine the CAS from the airspeed calibration curve and use that CAS when discussing the flight condition. Report the c.g. location for the tests.

2. For the phugoid mode, plot CAS as a function of time. On this curve, plot the points where $\theta = 0$. Determine the period, T, the time to half, $t_{1/2}$, and the number of cycles, $N_{1/2}$, to damp to one-half original amplitude.

3. Determine the period, T, and estimate the damping, $t_{1/2}$, of the Dutch roll oscillation.

4. Determine time to double or half, t_{double}, $t_{1/2}$ for the spiral mode. Plot the bank angle vs time.

5. Determine the ratio of δ_r/β and δ_a/β and express $C_{n_{\delta_r}}$ in terms of C_{n_β}, and $C_{\ell_{\delta_a}}$ in terms of C_{ℓ_β} at the trim point.

6. In the results and discussion section of the report discuss your observations both qualitatively and quantitively using time history plots or diagrams as necessary. Comment on the interrelationship between the normal modes of aircraft motion and mission requirements, specification requirements (lookup specifications in the FARs for the various modes of motion); and the effect of various physical aircraft parameters on rudder power and aileron power.

3. Do a set of sample calculations.

4. Notes:

a. Aileron deflection, δ_a, is defined as

$$\delta_a = \frac{1}{2}(\delta_1 + \delta_2)$$

where $\delta_1 =$ down deflection of right aileron

and $\delta_2 =$ up deflection of left aileron

To find the gearing, use the following information:

$$\text{Full yoke deflection} = \pm 106^\circ$$

and

$$\delta_1 = \pm 19^\circ$$
$$\delta_2 = \pm 19^\circ$$

b. The maximum rudder deflection, δ_r, equals $\pm 25^\circ$.

V speeds for the A-36

Speed	KIAS	Definition
$V_y = V_{R/C_{\max}}$	100	Maximum rate-of-climb speed
$V_x = V_{\gamma_{\max}}$	84	Maximum climb angle speed
V_{S_1}	62	Stall speed clean
V_{S_0}	56	Stall speed dirty
V_H		Speed at maximum power
V_A	139	Maneuvering speed
V_{FE}	122	Maximum flap extension speed
$V_{\text{gear operating}}$	153	Maximum gear operating speed
$V_{L/D_{\max}}$	110	Speed for maximum glide distance